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MEASURING OXYGEN AND CARBON DIOXIDE IN RED OAK TREES

Abstract.—A method is described for collecting gas samples from tree trunks by placing a permanent probe in the tree and withdrawing samples with a portable vacuum pump. Marked quantitative differences were found between the concentration of gases in tree trunks and the concentration of gases in the atmosphere.

Decay columns in trees may become inactive after the entry point has healed. The inactivation or dying of the decay organism may be due to the formation of adverse levels of gases in the tree trunk after the exchange of gases between the atmosphere and the inside of the tree has stopped (*4*). A study was conducted to develop a method for measuring gas concentrations in tree trunks and to determine if these levels were sufficiently different from those in the atmosphere to justify a more thorough study of gas levels in tree trunks.

Materials and Methods

The method developed to collect gas samples from tree trunks consists of placing a permanent probe in the tree and withdrawing samples from the tree with a portable vacuum pump. The permanent probe is used so that sampling can be repeated.

The probe consists of a 1/4-inch galvanized pipe. A brass on-off valve and a hose connection are sealed on one end of the pipe with Teflon[1] pipe dope. The other end of the pipe is threaded, and the length of the threading equals the depth the pipe will be placed in the tree. Before it is used, the probe is sterilized in an autoclave for 20 minutes at 15 psi.

[1] Mention of a product does not imply endorsement by the U. S. Department of Agriculture.

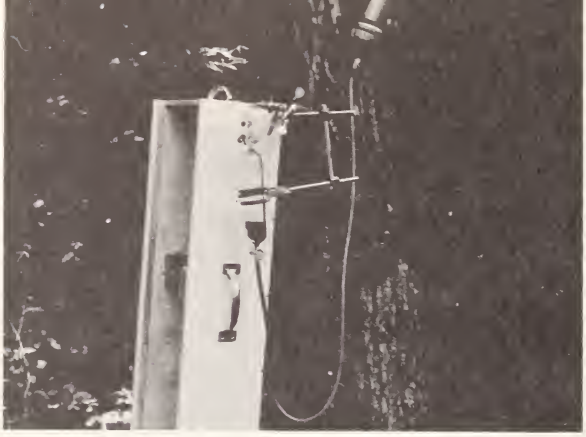

Figure 1.—Gas sampling apparatus and gas analyzer mounted on a red oak tree.

Before the probe is placed in the tree, a layer of outer bark is removed with a drawknife, and the exposed area is surface-sterilized with 95% ethanol. Next, an alcohol-sterilized increment borer is used to remove a core that can be examined for conditions inside the tree. The hole is then enlarged to the desired depth with an alcohol-sterilized 7/16-inch bit. The sterilized probe is placed in the hole by turning the probe with a pipe wrench until the probe is within 2 inches of the bottom of the enlarged hole. The hole is then sealed with a mixture of one part Venice turpentine and two parts beeswax to prevent gas leakage (*1*).

The portable vacuum pump is mounted on a framework made of 1/2-inch aluminum rods and a large support clamp. The framework is attached to the probe (fig. 1).

The portable vacuum pump consists of a gas-collecting cylinder connected to a mercury reservoir. The 250-ml gas-collecting cylinder has a 3-way stopcock on top and a 2-way stopcock on the bottom. This cylinder is mounted in the support clamp. The 3-way stopcock is connected to the probe with capillary glass tubing and 1/4-inch Nalgon plastic tubing, and it is connected to a portable gas analyzer (*3*) with 1/4-inch rubber tubing. The 2-way stopcock is connected to a mercury reservoir by 4 feet of 1/4-inch Nalgon plastic tubing. The reservoir is made of 2-inch galvanized pipe, 6 inches long, and holds 350 ml of mercury.

To operate the pump, the gas-collecting cylinder is filled with mercury by raising the reservoir. The mercury is then removed from the cylinder by lowering the reservoir to create a partial vacuum. The 3-way stopcock is opened so air in the tubing between the cylinder and the probe is pulled into the cylinder. This air is then passed out of the cylinder through the gas analyzer by readjusting the 3-way stopcock and raising the mercury reservoir. A sample is then pulled from the tree by opening the valve on the probe and the 3-way stopcock and lowering the reservoir.

After a sample of the desired size is collected the valves are closed, and the reservoir is raised so the gas can be forced into the gas analyzer.

The trees used in this study were northern red oak (*Quercus rubra* L.) over 10 inches d.b.h. At least 1 week elapsed between the time the probe was placed in a tree and the time the first sample was collected. This time allowed the air in the tree and the pipe to equilibrate.

Results and Discussion

This method gave reproducible results if care was taken to avoid the sources of error. The sources of error are: (1) the length of time required to collect the sample and (2) the size of the sample.

The sample should be collected as rapidly as possible, especially on trees from which the sample is difficult to collect. A sample collected rapidly (15 seconds) contained 4.2% carbon dioxide and 0.9% oxygen; whereas a second sample collected immediately after the first, but at a slower rate (60 seconds), contained 15.2% carbon dioxide and 0.4% oxygen.

The higher carbon dioxide concentration in the latter sample may have been due to the liberation of dissolved carbon dioxide when water inside the tree was subjected to a high partial vacuum for a longer period of time. In laboratory studies, when a high partial vacuum was placed on water that had been exposed to high levels of carbon dioxide, the gas collected contained over 50% carbon dioxide. Therefore, the shorter the sampling time, the smaller will be the amount of carbon dioxide liberated and the smaller will be the carbon dioxide contamination of the gas sample.

The size of the sample should be no larger than necessary. The sample size is especially important in trees that have openings to the atmosphere. On one tree with an artificial opening, a small sample contained no measurable carbon dioxide and 1.9% oxygen; whereas a large sample, collected immediately after the first, contained no measurable carbon dioxide and 11.7% oxygen. The higher oxygen level in the second sample is probably due to oxygen from the atmosphere being pulled into the gas sample when a large sample was collected.

A further reason for using a small sample is that, with repeated sampling, the gas composition in apparently sound trees also changed (table 1). Gas from the atmosphere was apparently being pulled into the tree because the oxygen concentration increased even though no openings were visible. By using a small sample, the contamination of the gas sample by gases from other places in the tree and by gases in the atmosphere can be minimized.

By standardizing the procedure, reproducible results were obtained. In a healthy tree, which was sampled five times at weekly intervals in April and May 1965, carbon dioxide varied from 13.5% to 16.5%, and oxygen varied from 5.5% to 7.5%. These results are similar to those reported by Chase (*2*), who used a different method to collect gas.

These data collected from the various trees also show that the gas concentrations in tree trunks may be markedly different from the gas concentrations in the atmosphere. The concentration of carbon dioxide in the atmosphere is approximately 0.03%, and the concentration of oxygen is approximately 21%. The carbon dioxide concentration in tree trunks may be several hundred times higher than the atmospheric concentration of carbon dioxide, and the oxygen level in tree trunks may be less than 25% of the atmospheric concentration of oxygen.

Table 1. — Changes in gas concentrations with repeated sampling

Sample No.[1]	% CO_2	% O_2
1	30.7	2.3
2	22.4	8.3
3	20.5	10.7
4	20.3	10.7
5	16.9	12.6

[1] All samples were taken within a 40-minute period and were approximately 150 ml each.

Since the method reported here was effective in measuring the composition of gases in tree trunks, and since a marked difference was found between the levels of gases in tree trunks and the levels of gases in the atmosphere, more detailed studies will be conducted to determine the levels of gases both in healthy trees and in decaying trees.

Literature Cited

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